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Agricultural Research

ARS's Global Research Network

In our ever-shrinking world no human activity is sufficient to itself. The practices and problems of modern agriculture, for example, know no boundaries. Local problems often have international solutions. A problem in one country may have its solution in another. These may involve sharing better technology, or enlisting new allies from the natural world. To be successful, such efforts require overseas facilities.

Seven laboratories—each with a specific mission—comprise the overseas arm of the Agricultural Research Service. Four of them are devoted to finding biological controls for exotic diseases and insect and weed pests that have found their way into the United States. The other three are concerned with special problems in exporting agricultural commodities, preventing the spread of animal diseases, and encouraging the production of food and ornamental crops in regions currently growing opium poppies.

Originally established in Auch, France, in 1919, the European Parasite Laboratory is the oldest overseas Federal biological control facility. In 1920, the lab was moved to Sevres, a Paris suburb. Starting with its original mission to find natural enemies of the European corn borer, the lab has identified the natural enemies of more than 65 target insects and 11 weeds. In 1980 alone, the European Parasite Lab shipped more than 5 million specimens of several hundred species of beneficial organisms to the United States for use in combating exotic pests. In addition to cooperating closely with other USDA agencies, the lab also helps many other countries—such as Chile, Brazil, Morocco, and Nepal—battle their pests with introduced parasites and predators.

Another European ARS facility, the Biological Control of Weeds Laboratory, Rome, was established in 1959. Scientists at the Rome lab have found and evaluated insects that have helped partially or completely to control puncturevine, Mediterranean sage, Scotch broom, tansy ragwort, and musk thistle, just to mention a few of the noxious weeds entering this country. Such weeds cut into U.S. crop yields, take over rangelands and pastures, and cost U.S. farmers and ranchers more than $7 billion in weed-control measures and millions in livestock deaths from toxic plant poisoning each year.

The Biological Control of Weeds Laboratory near Buenos Aires, Argentina, was set up in 1962 to find natural enemies of alligatorweed, an aquatic plant that clogs American waterways and interferes with irrigation and also boating and fishing.

The Buenos Aires lab has recently expanded its role to include research on natural insect pest enemies of dung beetles, velvet-bean caterpillars, and others.

The newest of the overseas biological control laboratories is the Asian Parasite Laboratory at Seoul, South Korea. Established originally at Sapporo, Japan, the lab was moved this year to Korea to expand research on gypsy moths, Mexican bean beetles, pear psylla, scale insects, and other pests of Asian origin that cause economic losses to American farmers.

The ARS Animal Disease Laboratory, Nairobi, Kenya, has probed exotic diseases since 1951. Livestock owners around the world benefited when the lab developed the first diagnostic test for African swine fever.

Since Africa harbors animal diseases not presently found in the United States, the Kenya lab is an invaluable source of disease organisms for study by scientists at the ARS Plum Island Disease Center in New York.

Located at one of the world's greatest ports, the European Marketing Research Center at Rotterdam, The Netherlands, provides a wide range of services. It was established in 1969 in response to the needs of U.S. exporters for onsite technical assistance in solving loss and damage problems related to shipping fruits, vegetables, grains, animals and animal products to European markets.

The Rotterdam lab joined several U.S.-based ARS research labs to form a network for monitoring and studying—from origin to destination—individual shipments of U.S. agricultural products. This network not only has remedied various shipping problems that could threaten expansion of export markets—including excessive chemical residues and inadequate packaging—but also has helped revolutionize the U.S. overseas container industry.

The lab's work bolsters the U.S. economy both by maintaining and improving the existing U.S. overseas markets and by gaining new ones.

Perhaps the most unusual ARS venture overseas is the Narcotic Substitution Project, Chaing Mai, Thailand. Established in 1973, this research program involves one ARS scientist working with many Thai scientists to coordinate 30 research projects. The Thai scientists are provided with materials and expertise to encourage local farmers to substitute other crops for the opium poppy, large amounts of which reach the United States illegally.

The project has already brought into production strawberries, coffee, and chrysanthemums which are sold to Thailand's domestic and export markets. Other crops like peaches, shiitake mushrooms, wild silk, and tea further enable Thai farmers to profitably exploit a wide range of ecological niches and thus forsake the illicit poppy trade. For example, by switching to coffee growing, Thai families can raise their incomes to more than $2,000 a year, compared to less than $500 from poppies grown for opium.

Without overseas laboratories, various research projects would be rendered unfeasible. At best, many projects would require far greater outlays of money and personnel. Some projects require foreign-based scientific expertise. Others, like our broadly based, biological control programs, would be hampered without foreign sources of beneficial organisms. And labs abroad are necessary to study exotic diseases and insects in their countries of origin so as not to jeopardize the vast U.S. livestock industry.

American agricultural exports—a positive force in U.S. international trade balances—would not have reached their present dollar volume without research programs that painstakingly analyze American shipments to foreign ports.

ARS's overseas research spreads goodwill by helping other nations fight their disease, insect, and weed problems, and enables people everywhere to enjoy the bountiful fruits of American farms and industries.

Henry Becker III
Beltsville, Md.

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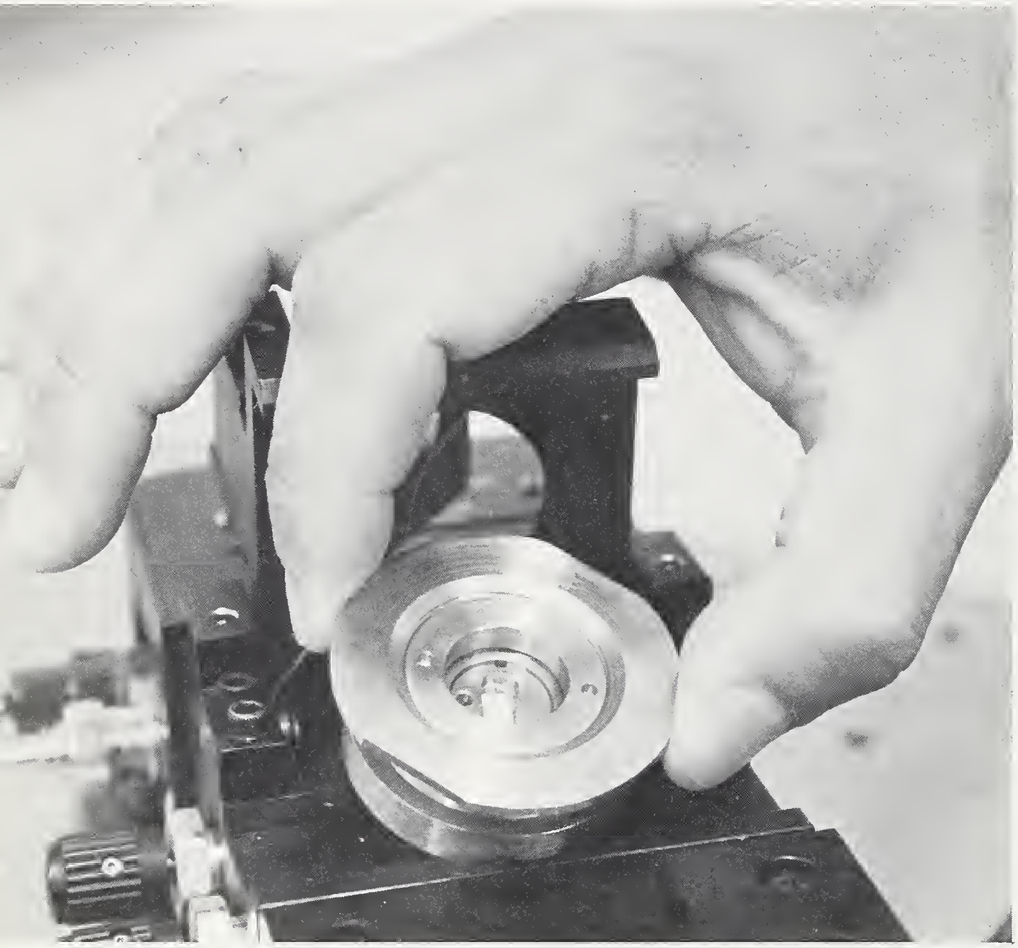
Cover: A wasp called *Lemophagus curtus* injects her eggs into the larva of a cereal leaf beetle, thus destroying the larva before it can mature. *Lemophagus curtus* is one of several parasitic wasps brought from Eurasia to the United States in a biological control program aimed at the cereal leaf beetle—itself a Eurasian import. Article begins on page 8. (PN-6861)

Light-Generated Sound Probes Lignin Enigma



Various components of the lignin in the plant material contained in this round chamber can be detected as they heat and cool in response to intermittent light, creating air pressure changes. The chamber is being placed in an acoustic detector which will record the air pressure changes as sounds. (0982X1111-4)

Differences in sounds generated by light could be one of the long-sought keys to unlocking the mysteries surrounding lignin. Despite years of studies employing various approaches, little is known about the incredibly complex structure of lignin, the natural cement that binds cellulose fibers in plant stems and prevents enzymes from digesting cellulose. Now a scientist has turned to a technique known as photoacoustic spectroscopy in the search for new ways of removing lignin from wood or crop residues like wheat straw and corn stalks. The goal is to exploit lignin for processing into alcohol and other materials for industry, or into feed for livestock.

Studies by chemist J. Michael Gould, Northern Regional Research Center, Peoria, Ill., mark the first use of photoacoustic spectroscopy to investigate natural lignin. In using this technique, Gould places a sample of wood or straw into sealed metal chambers, then exposes it to light flashing more than 100 times a second. As the light turns on and off, the lignin alternately warms and cools, changing the air pressure within the chamber. A microphone in the chamber picks up the rapid changes in air pressure as sound. Various components of lignin emit sounds at different wave lengths of light which Gould records and studies.

An important advantage of photoacoustic spectroscopy is that it can analyze an intact sample of opaque material, like lignin, without changing its composition. On the other hand, practically all the chemical and spectroscopic information about lignin has been derived from fragments obtained by either chemical or mechanical means. Lignin cannot be removed from wood without partially degrading the lignin, thereby changing some of its physical and mechanical properties. Gould says that conventional absorption spectroscopy, while effective for many materials, has to be ruled out for these studies because light cannot easily pass through lignin.

Lignin is as abundant as it is complex. Since lignin makes up 15 to 25 percent of a plant cell wall, it ranks as nature's second most abundant organic material, "exceeded only by cellulose," Gould says. Further, more energy is stored in the chemical bonds of lignin than in any other component of the plant, including cellulose.

The enigmatic complexity of lignin has so far thwarted efforts to efficiently release these vast stores of energy. (Agricultural Research, May 1980, cover and pp. 10-12). "Lignin in crop residues prevents efficient utilization of either cellulose or hemicellulose for fermentative ethanol production. And it interferes with animals' digestion of green plants, hay and crop residues," Gould says.

In scientific literature, the structure of lignin is described as "amorphous" and "polymeric." Its exact formula is unknown. Gould thinks that lignin exists in nature "as a three-dimensional polymeric network of essentially infinite molecular weight." Put another way, it is a gigantic molecule with no theoretical limit, and an actual limit set only by the structure containing it.

Gould sees possibilities for utilizing lignin by trying to emulate the role of decomposer organisms. In nature, lignin is degraded by several organisms of which the most intensely studied are the Basidiomycetes, or white-rot fungi. The mechanism of this degradation process is largely unknown, but apparently the fungi use excreted oxidants. "If we can determine which oxidants are used by these organisms, we can imitate the natural process chemically," Gould says.

Chemical delignification would end the waste caused when the fungi go on

Biochemist J. Michael Gould aligns the equipment for photoacoustic analysis of the lignin in plant material. (0782X731-15)

to metabolize cellulose or products they get from the lignin.

Gould is seeking clues to which oxidants the fungi use by studying the chemical and physical changes that occur within the lignin polymer during biodegradation. It is these changes that the photoacoustic spectroscopy technique helps study as a function of light-generated sound.

The instrumentation employed, which Gould constructed from optical and electronic components, has two of the sealed chambers with equal light beams focused on each. Sound from each chamber is amplified, recorded, and read out as plotted curves representing the absorption of light by the sample.

"Lignin absorbs light primarily in the ultraviolet region of the spectrum," Gould says, "where cellulose and hemicellulose do not absorb appreciably." Ultraviolet light on wood and wheat straw, therefore, selects for information from lignin in the sample.

Ultraviolet absorption curves for lignin in the wood of white pine, oak, and maple trees exhibit a broad peak, or maximum, near 300 nanometers (billionths of a meter) and a "hump," or less intense maximum, at about 350 nm. "Isolated lignin fragments, on the other hand, typically have a single absorbance maximum near 280 nm," Gould says.

Light absorbed at greater than 300 nm by lignin in its native state indicates "highly conjugated structural components," that is, compounds with alternating single and double bonds between carbon atoms. This condition could result from natural aging or from oxidation by singlet oxygen, a highly reactive form of oxygen produced by the action of sunlight.

"Such photochemical oxidation of lignin is quite apparent on the outer surface of field-dried, senescent wheat straw," Gould says. The mature straw absorbs a large proportion of the ultraviolet light in the long wavelength

bands, 350 to 450 nm. Lignin in less mature wheat straw and on inner surfaces of the mature straw absorbs light at lower wavelengths, 280 to 320 nm, Gould says.

Lignin compounds that absorb light at more than 300 nm could act as photosensitizing centers on surfaces illuminated by sunlight. Additional photochemical oxidation of the lignin polymer would cause important changes in its physical and biomechanical properties, Gould says.

Photoacoustic spectroscopy with ultraviolet light alone cannot determine the fine structure of lignin, Gould says, but it can be used with other techniques. He has started using infrared light. "The infrared absorption patterns in conjunction with the ultraviolet patterns will provide a great deal of information about the structure of lignin in its natural state."

J. Michael Gould is located at the Northern Regional Research Center, 1815 N. University, Peoria, Ill. 61604. ■

Gould compares a printout and the live image (upper left) showing the photoacoustic analysis of the lignin component in a sample of newsprint paper. (0782X731-33)

A New Process to Degrade Lignocellulose

Another approach to utilizing celullose involves making it soluble through hydrolysis. However, present methods of hydrolysis are based on the use of acids and enzymes, and are impractical. They require large amounts of water, elaborate controls, or expensive product-recovery procedures.

Progress toward developing a practical process to hydrolyze cellulose combines use of a swelling agent followed by gamma radiation. Youn Woo Han and his colleagues E.B. Lillehoj, Judy D. Timpa, and Alex Ciegler, all microbiologists, are conducting the research at ARS' Southern Regional Research Center, New Orleans, La.

The researchers treat lignocellulosic material with three parts (weight to volume) of a swelling agent such as sodium hydroxide, then subject it to gamma irradiation from cesium-137, a nuclear waste material, at dosage levels up to 50 Mrad. The resulting product is a dark, brownish liquid, with a sweet molasses flavor. It contains a variety of sugars and small fragments of lignin degradation products. The liquid can be diluted to a solution of any desired sugar concentration.

Cellulose hydrolysis by high-energy irradiation is not new, Han says, but the dosage level required heretofore was too high for practical use. This problem was remedied by properly combining chemical pretreatment with irradiation.

Moreover, the use of cesium-137, a nuclear waste material, should make the process more attractive to industry than the previous method of using a high-energy cathode ray or gamma radiation from cobalt-60.

The new process is the reverse of conventional methods in which a diluted sugar solution is obtained and then concentrated to a desired level. Furthermore, it produces a sugar solution that is sterile and ready to use for fermentation or other aseptic processes, thereby eliminating the expense of sterilizing large quantities of fermentation broth.

With this process, cellulose and hemicellulose as well as the lignin portion of the plant material is solubilized. Once solubilized, the separation and utilization of lignin and lignin degradation products becomes relatively simple.

Looking toward the future, the new process not only has the potential for utilizing vast amounts of lignocellulosic agricultural wastes, but also large quantities of cesium-137, now considered an undesirable byproduct of fission from nuclear reactors.

Youn Woo Han, E.B. Lillehoj, Judy D. Timpa, and Alex Ciegler are located at the Southern Regional Research Laboratory, 1100 Robert E. Lee Blvd., P.O. Box 19687, New Orleans, La. 70179.—(By Neal Duncan, New Orleans, La.)

Wheat Tillers Pinpoint Plant Stress

Results of research on detecting stress in wheat plants is supporting the truth of Shakespeare's axiom that "What's past is prologue."

By "reading" the tillers of a wheat plant, ARS plant physiologist Betty Klepper and soil scientist Ron Rickman, Pendleton, Oreg., are able to determine if and when a plant has been subjected to stress, and how severe the damage was. With this knowledge, growers may adjust their management practices either to correct the current stress or reduce future ones.

Wheat tillers are rooted branches that determine the number of heads a plant will produce. A wheat plant makes more tillers than its uses, normally aborting a third to a half. Environment determines how many tillers survive to make heads, and can be influenced by such management practices as planting and tillage techniques, fertilization, weed and insect control, and irrigation. The number of tillers that survive to form heads, along with the spikelets per head, kernels per spikelet and weight per kernel, are the components that control yield.

"A plant creates itself out of the world around it," says Klepper. "Water, minerals and nutrients from the soil are needed, as are oxygen and carbon dioxide from the air. All are packaged together as building blocks. If one of these blocks isn't there, it's like running out of bricks or mortar when building a house: construction stops."

During the crucial tiller-making process, an unstressed wheat plant makes its tillers at a certain time during leaf formation in accordance with a strictly regimented pattern. Any divergence from this pattern means the plant is under stress.

Rickman and Klepper have developed a numbering system that identifies all of the leaves and tillers on a wheat plant so that the history of the plant's development can be studied and evaluated. Knowing *when* a stress occurred narrows the alternatives as to *what* the stress was. Once the cause is identified, the effects of management decisions on yield can be appraised.

Under Klepper and Rickman's identification system, leaves of the main stem of a wheat plant are numbered in order of appearance. The primary tiller of the plant embryo is numbered T0. The first leaf is designated L1, the second L2, and so on. Tillers developing from the buds at the base of each leaf are numbered for the leaf with which they are associated. The tiller from L1 is T1, that from L2 is T2, and so on.

Once the pattern of tiller development is known, reading for stress is easy. A sample of young seedlings is removed from the field and inspected. Matching any missing, dead, or partially formed tillers to the corresponding stage of leaf development reveals when the stress took place.

For example, on "Stephens," a soft white winter wheat, T1 normally develops when the fourth leaf on the plant's main stem begins to appear in late fall. By the time the sixth leaf on the main stem appears in early spring, four tillers, T0, T1, T2, and T3, are visible. If any tillers are missing, the plant has had problems.

Rickman and Klepper have also charted emergence curves that growers can use to predict when the next tiller will appear. If the tiller fails to appear on schedule, the grower can assume the crop is under stress and can decide whether to take remedial action.

The emergence curves are based on heat accumulation in the plant. Closely related to air temperatures, plant heat accumulation affects the time interval between leaf and tiller formation. The scientists measure heat accumulation in units of degree days—the average daily temperature minus the temperature at which a specific wheat variety stops growing. A certain number of degree days, which can be correlated to calendar days, is required for the plant to generate a leaf or tiller.

Although the concept of heat accumulation is an old one, it has never been applied to wheat tiller development. Rickman and Klepper say that their work with heat accumulation as well as tiller development and reading can be applied to other cereal crops.

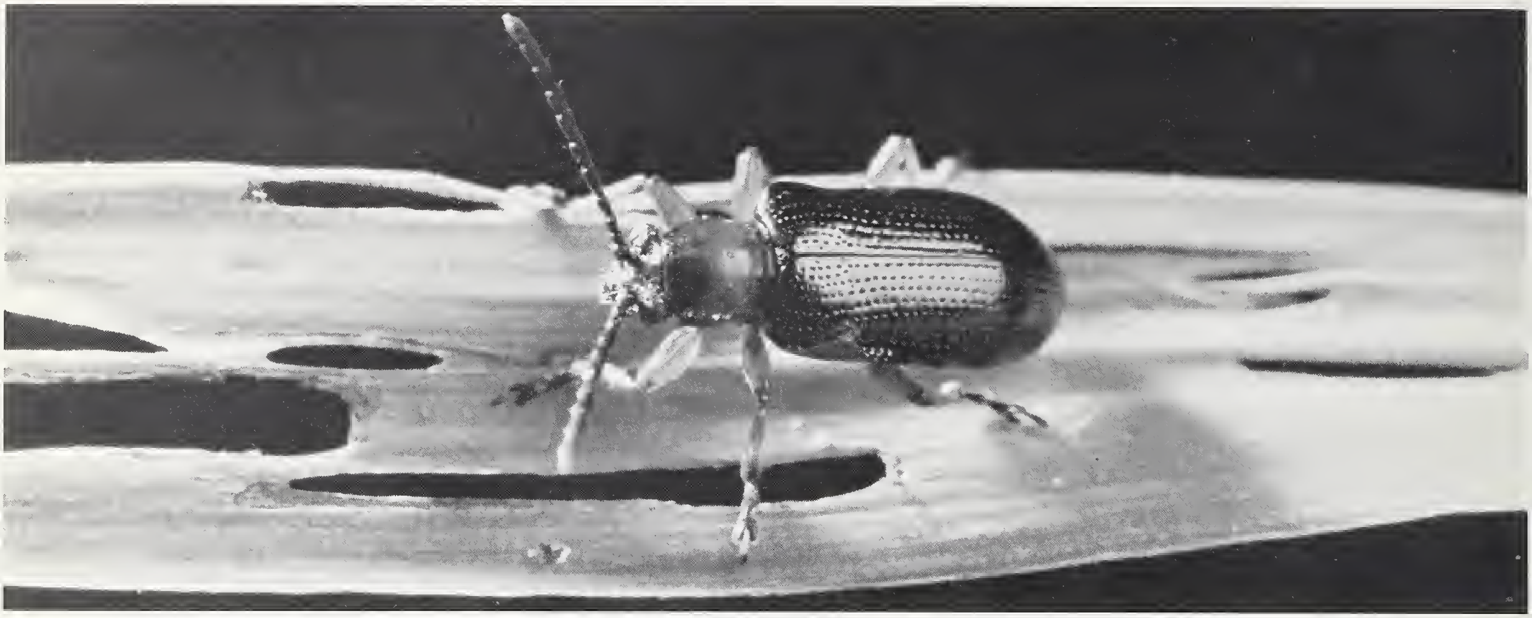
Protecting or relieving wheat plants from stress can have a chain reaction effect on yields as each tiller that survives can produce a tiller of its own which, like the primary tiller, can produce a grain-filled head.

The two scientists are now numbering and identifying wheat roots. Their goal is to relate root survival to tiller survival and learn what impact this relationship has on yield.

"No one has ever examined the field-grown wheat root system in this kind of detail before," says Rickman. For more than a year, he and Klepper have been working with Robert K. Belford, a soil scientist and root specialist visiting Pendleton from Oxford, England. Belford works for the Letcombe Laboratory of the Agriculture and Research Council, England's equivalent to ARS.

Ron Rickman and Betty Klepper are located at the Columbia Plateau Conservation Research Center, P.O. Box 370, Pendleton, Oreg. 97801.—(By Lynn Yarris, Oakland, Calif.)■

Saga of the Cereal Leaf Beetle War



A cereal leaf beetle is poised to feed on a barley leaf already showing adult feeding scars. Wheat and oats also suffer damage from this imported pest. (0882X887-30A)

The cereal leaf beetle—once a scourge of wheat and other small grain crops in the eastern and central United States—is now under control thanks to the creative harnessing of Mother Nature.

ARS research entomologist Stanley G. Wellso says, "After a 20-year fight we are winning the war. We have developed excellent biological means to control the cereal leaf beetle population. Extensive spraying has not been necessary for several years. Only about 20,000 acres were sprayed in 1981, all in the central Atlantic States. Spraying is down drastically from the 1,616,807 acres treated in 1966."

Wellso led a USDA research group at Michigan State University in developing the biological control agents, working with colleagues from MSU, Purdue University, and USDA's Animal and Plant Health Inspection Service (APHIS).

The beetle was first identified in Galien Township, Berrien County, Michigan, in 1962. As the beetle spread, field losses as high as 55 percent in spring wheat and 23 percent in winter wheat were reported.

Michigan State University entomologist Dean L. Haynes speculates that the first beetles probably arrived from overseas sometime between 1947 and 1949. The population grew enough to cause farmers to spray some fields in 1959.

After the beetle's identification in 1962, Michigan, Indiana, and the USDA's Animal and Plant Health Inspection Service established a quarantine program and began spraying with insecticides to contain and destroy the pest.

Even so, the beetle rapidly spread eastward, eating oats, barley, wheat, rye and corn as well as weeds such as wild oats and quackgrass, and forage grasses such as timothy, ryegrass, orchard grass, and reed canarygrass. Beetles are now found from North Carolina and Tennessee north to Quebec and Ontario and west to Missouri and Wisconsin.

Both adults and larvae feed on leaves but the larvae are more numerous and thus more destructive. Larvae are sedentary, hence also cause more damage per infested plant, while adults usually move through a field feeding and laying eggs over a wide area.

Robert F. Ruppel, an MSU entomologist, found that beetles prefer young plants and new growth. Beetles inflict especially heavy damage to late-planted tall grains and early-planted spring grains undergoing lush growth engendered by unseasonably warm weather. Oats and barley can suffer total loss should other environmental conditions, such as drought, add plant stress to beetle damage.

While the battle was being waged with quarantine programs and large scale spraying, scientists went to work seeking other, better controls. Among various approaches to the problem, they began the field testing of more than 30,000 lines of wheat, oats, and barley for natural resistance to the beetle.

Meanwhile the spraying efforts underway significantly reduced crop losses. However, spraying was expensive and not a desirable long-term control method because of possible harm to the environment. The best long-term results came from the search begun in 1963 for parasites in European areas where the cereal leaf beetle is common.

Scientists working at USDA's European Parasite Laboratory, near Paris, collected five parasites for North America. Four of the parasites were eventually established at MSU's Kellogg Biological Station near Kalamazoo, Mich. In 1966, APHIS established a laboratory in Niles, Mich., for the high volume production and distribution of parasites.

One of the most effective insects has been *Anaphes flavipes*, a parasitic wasp that injects its eggs into the cereal leaf beetle's eggs. The wasp eggs hatch and develop inside the beetle's eggs,

The tiny *Anaphes flavipes* wasp injects her eggs into the egg of a cereal leaf beetle. Instead of beetles, wasps will emerge from the egg. *Anaphes flavipes* is the only imported wasp which parasitizes the beetle egg; the other three wasps parasitize the beetle larvae. (PN-6862)

Top: Entomologists Stanley Wellso (left) and Robert Hoxie inspect seedlings of a cereal plant bred for resistance to the cereal leaf beetle. (0882X888-7A)

Above: The way it was in 1965: a barley nursery in Barrien County, Michigan, shows extensive cereal leaf beetle damage. White leaves signify heavy larval damage; under a massive attack, an entire field can appear white. (PN-7025)

feeding on and thus destroying the developing insect.

The other parasites, *Tetrastichus julis*, *Lemophagus curtus*, and the most recent introduction, *Diaparsis temporalis*, are also wasps. They inject their eggs into cereal leaf beetle larvae where they hatch and feed, killing the larvae.

The APHIS laboratory, directed by supervisory entomologist Thomas Burger, provided farmers, Extension Service workers, researchers and others with "bouquets" of grain plants infested with cereal leaf beetle eggs and larvae along with their parasites. The bouquets were subsequently transported to other fields infested with the beetles but not the wasps. After about 3 years, these newly established parasite colonies provided infested bouquets for distribution to other sites.

Once the parasites become established in an area, they typically reduce beetle populations about 60 percent and grain losses to less than 1 percent.

Burger notes that, "Today, it is hard to find a beetle in areas in Berrien County where we used to collect 10,000 beetles a day. And now when we do find them, 99 percent have parasites."

Reece I. Sailer, University of Florida entomologist says, "The cereal leaf beetle project is unquestionably an outstanding example of biological control through importation of natural enemies. It is, in fact, the first instance

In a State-Federal cooperative research program, Michigan State University students Mary Jo Drechnowicz (foreground), Julia Graber (back left), and Michele Giele helps Wellso collect summer adult cereal leaf beetles from a field of reed canary grass for laboratory studies. (0882X888-29A)

in which a pest of an annual crop grown in a temperate continental area has been successfully controlled by imported natural enemies."

Because control of the cereal leaf beetle is very good in most infested areas, the ARS and APHIS programs have been phased out. A few states still rear and distribute the wasps locally.

In the meantime, research on breeding crops resistant to the beetle began to produce results. The most advanced achievement of the breeding work has been the release of a moderately resistant soft red winter wheat variety, Downy, developed by ARS research agronomist John J. Roberts and research entomologist Robert L. Gallun at Purdue University. Downy yields well under beetle-infested conditions, says ARS research entomologist James A. Webster, now stationed at Stillwater, Okla.

Early screening in small grain nurseries turned up little resistance in oats and barley lines, but later selection and breeding efforts have produced some slightly resistant germplasm. Twelve nonpubescent (hairless) lines of barley germplasm with resistance to the cereal leaf beetle are now available from the ARS Small Grain Collection, Beltsville, Md.

Should the beetle threaten crops in the Great Plains, Webster says six lines of hard red spring wheat with resistant germplasm have been released to plant breeders. Resistant lines of soft red winter and hard red winter wheats are also available to breeders.

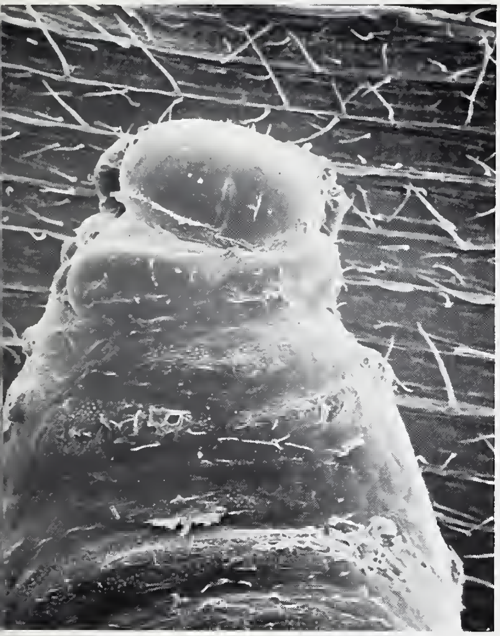
Although reliance on host plant resistance can be very efficient and labor free, it takes several years to find resistant germplasm and more time to breed it into productive varieties.

Purdue, MSU, and ARS scientists worked with plant materials from the ARS Small Grain Collection. They found that resistance in wheat lines, based on reductions in egg laying by adults and feeding by larvae, was due to pubescence, or hairiness, of the leaves. They also found that leaf hair length was more important than density in deterring egg laying.

Leaf hairs afford little nutrition to the larvae. Since they must first chew through the pubescence to reach the leaf surface, the hairs may interfere with the larvae's digestive system and also the critical time needed to complete their first feeding.

Thirty lines of soft red and soft white wheats carrying resistance to the beetles are now under test at the University of Maryland, Webster adds.

Wellso points out that battling the beetle with plant resistance as a weapon is not simple. Beetles encountering resistant wheat appear capable of sustained feeding and egg laying even in the absence of other host plants. The beetles place their eggs on those plants with shorter, less dense pubescence.



Top: An electron micrograph shows a cereal leaf beetle larva on a hairy leaf of hard red winter wheat. Longer leaf hairs interfere with the larva's movement, feeding habits, and digestive system, thus reducing its damage and its chances for survival. (PN-7024)

Above: In spinoffs from the cereal leaf beetle model, other parasites have been imported to control other pests. This *Microceonus oethiopoides* wasp injects her eggs directly into an alfalfa weevil, which becomes sterile and then dies. (0582X416-24)

Moreover, some beetles apparently overcome plant resistance, so while plant resistance may reduce beetle numbers, feeding, and egg laying, it does not provide total protection.

Genetic mutations are always a possibility and may produce a strain of beetles able to survive on pubescent plants. Whether the beetle or the plant wins this competitive battle hinges upon man's ability to manipulate small grain germplasm genetically.

Another part of the plant resistance problem, Wellso says, is that environmental differences cause pubescence—and therefore beetle resistance—to vary from one leaf to the next on the same plant, as as well as among plants, and from one year to the next. Leaf length, temperature, and moisture influence length and density of leaf hairs, or trichomes, in a specific area of a leaf.

"We now can determine the resistance rating of wheat to the cereal leaf beetle, even without the beetle being present. Trichome length and density are influenced by the environment, so it is better to evaluate wheat resistance from plants grown in the field or under standardized laboratory conditions", Wellso says.

The beetle is now established on farmlands that produce 32 percent of the U.S. production of oats, 15 percent of the wheat, and 6 percent of the barley. Although the imported parasites have been effective in areas the beetles have occupied so far, conceivably the pest could move into an area where the environment favors beetles more than parasites. Serious yield losses could then occur, Wellso says.

"That is why we have worked to develop germplasm carrying beetle resistance," he adds. "If the beetle does overcome the parasites in some specific geographic area, the plant breeders will have some tools to work with."

Other approaches may help, too. In a study with oats, Webster found that higher seeding rates could partially compensate for beetle damage. Higher seeding rates resulted in more beetle eggs and larvae per square foot of ground area. However, they were spread over more plants, so there were fewer eggs and larvae per plant in the high seeding rate area than in the low seeding rate area.

"We believe that planting oats at less than recommended rates, while economically feasible in some parts of the country, is not a sound practice in cereal leaf beetle infested areas," Webster says.

The cereal leaf beetle war is not over. It has simmered down to the tactic of spraying to protect small grain yields in newly infested areas. Spraying may be necessary for 3 to 5 years so parasites can catch up with the new population and bring it down to a level that does not seriously reduce yields. This is happening now in Virginia, Wellso says.

"The beetle is also moving northwestward into the dairy country of Wisconsin where spring oats are common. Releases have been made there and samples show 80 percent of the beetles now have parasites. We hope that the harsh winters and hot, dry summer soils of the Great Plains will limit the spread of the beetle into the wheat country, but the potential is there," Wellso warns.

Waging war against the beetle required development of a population control system. To do so, the researchers had to study, and understand, the interactions between the beetle population and the small grains, the parasite populations, and the other environmental factors. Then they were able to develop a model to predict cereal leaf beetle population patterns. Much of this work was led by MSU entomologist Dean L. Haynes.

The survey and parasite rearing and distribution system developed by the research team now serve as a model for other insect control programs, particularly that against the alfalfa weevil, Burger says. The Niles Laboratory now produces five parasites of the alfalfa weevil for distribution in 39 states.

Although the cereal leaf beetle situation is more or less under control, researchers cannot drop their guard. Webster points out that at least six other exotic small grain insects now live in countries that ship large quantities of products to the United States.

Entomologists throughout the United States are watching for the senn pest (Middle East), the nutgrass armyworm (Africa and Hawaii), the common crane fly (Europe), the cereal leafminer (Middle East), the wheat chafer (Europe and the Middle East), and the wheat bulb fly (Europe). Every one of these destructive insects has the potential for damaging our small grains, should they be introduced. If this happens, it is hoped the research techniques developed with the cereal leaf beetle program will be of value in combating other small grain insects.

Stanley G. Wellso is located in Rm. 147, Natural Science Bldg., Michigan State University, East Lansing, Mich. 48823—(By Ray Pierce, Peoria, Ill.)■

Quick Test for Sugarcane Disease

Counts of bacteria in the stalk juice of sugarcane can help breeders quickly identify varieties that are the most tolerant or susceptible to damage by ratoon stunting disease (RSD).

A major worldwide disease of sugarcane, RSD exhibits no distinctive external symptoms, yet significantly reduces yields, especially when the crop is grown under drought conditions. RSD causes sugarcane stalks to be shorter, lighter weight, and smaller in diameter. All commercially grown sugarcane is susceptible to RSD, which is easily spread by cultivating and harvesting equipment. Five to 10 percent of last year's $17 billion world sugarcane crop was lost to RSD.

In 3 years of field tests involving 20 sugarcane varieties, ARS scientists determined that the effects of RSD on crop yields are related to the numbers of RSD bacteria in the stalk juice. The research was conducted by plant pathologist Hideo Koike and plant physiologist G.T. Benda, in cooperation with plant pathologist A. Graves Gillaspie, Jr.

Field testing has proven reliable in determining the effects of RSD on yield of sugarcane varieties. However, the complexity and size of the field experiments limit testing to about 20 varieties at a time. Even a small-scale field test involves the planting of considerable stalk material, extensive space, and about 3 years of growing time. Because sugarcane breeders need a simpler, faster method of testing the RSD tolerance or intolerance of a large number of sugarcane selections, the bacterial count approach offers a possible alternative.

In predicting yield reductions from RSD, only the highest or lowest bacterial numbers are used to identify varieties susceptible or tolerant to RSD injury. As expected, tolerant varieties have the lowest numbers of RSD bacteria and susceptible ones the highest.

Hideo Koike and G. T. Benda are located at the U.S. Sugarcane Field Laboratory, P.O. Box 470, Houma, La. 70361. A. Graves Gillaspie, Jr., is located at Bldg. 004, Rm. 201, Beltsville Agricultural Research Center-West, Beltsville, Md. 20705.—(By Neal Duncan, New Orleans, La.)■

It Takes a Fungus To Know One

Fungus vs. fungus. That matchup may someday gain agriculture the upper hand in its battle against verticillium, one of the world's worst diseases of crops.

Plant pathologist James J. Marois, Beltsville, Md., and his colleagues found that the common soil fungus, *Talaromyces flavus*, vigorously attacks verticillium infestations in fields of eggplant. Now the researchers are testing *T. flavus* as a biological control agent against verticillium of cotton, potatoes, and alfalfa. In the United States, the disease causes over $100 million in annual damages to cotton and over $50 million to potatoes.

Growers currently depend upon fumigants to fight verticillium. But fumigants are expensive, difficult to apply, and not overly successful. Moreover, fumigants sometimes adversely affect the environment. And crop rotation, although a valuable method for controlling other diseases, exercises little effect on verticillium because it attacks too wide a range of host crops.

Change may be on the way, fueled by results of the field tests which pitted *T. flavus* against verticillium of eggplants. Plants treated with *T. flavus* developed at least 75 percent less verticillium than untreated plants at the Agricultural Research Center, Beltsville, Md. The fields were heavily infested with verticillium organisms, built up during previous years of testing tomato plants for resistance to the disease. Other tests at Bridgeton, N.J., showed that *T. flavus*-treated eggplants sustained 67 percent less verticillium damage than those untreated.

Yields were higher for treated eggplants in both tests. At Bridgeton, for example, treated plots outyielded untreated plots by 71 percent. Working cooperatively with Marois in these tests were plant pathologist Steven A. Johnston of Rutgers University, and mycologist Michael Dunn of the University of Maryland.

Marois says that the discovery of *T. flavus* as an aggressive enemy of verticillium is a classic case of soil ecology studies paying off. Different strains of verticillium fungus, borne in the soil, can infest virtually every cultivated crop. Yet every ounce of soil harbors thousands of species of microorganisms, each competing for survival, including many of verticillium's natural enemies.

To exploit nature's design, Marois ran greenhouse tests in which he screened 34 species of fungi as likely biocontrol candidates. He tested these fungi, not in conventional sterile growth plates, but in greenhouse pots containing eggplant seedlings. Soil in the pots was inoculated by adding some drops of water-suspended test organisms. Six species proved to inhibit verticillium significantly.

Eight weeks later, the eggplant seedlings were transplanted into verticillium-infested fields. Of the six species of fungi tested, only *T. flavus* inhibited verticillium. High populations of *T. flavus* had built up around the eggplant roots, and apparently protected the seedlings from verticillium just "waking up" from winter dormancy.

Considering the technical difficulties in controlling verticillium chemically, the discovery of *T. flavus's* role as an easily applied biological control agent may appear disarmingly simple. But Marois could not have designed and carried out his eggplant project without first carefully studying the population dynamics or fluctuations of the many microorganisms that live in the soil with verticillium fungi.

Marois says that variations of his greenhouse system for inoculating eggplants with *T. flavus* can be designed to work for other crops. Seed potatoes, for example, can be dipped into a solution containing *T. flavus* before planting them into verticillium-infested soil. He is confident that agricultural science will enlist more allies from the ranks of fungi to help fight diseases.

James J. Marois is located in Rm. 274, Bldg. 011A, Beltsville Agricultural Research Center-West, Beltsville, Md. 20705.—(By Stephen M. Berberich, Beltsville, Md.) ■

Above: Symptoms of verticillium disease include yellowing and wilting—especially on only one-half of each leaf. (0782W748-27)

Left: To determine the effectiveness of the fungus *T. flavus* as a verticillium control agent, plant pathologist James Marois inoculates the soil around eggplant seedlings with a suspension of *T. flavus* spores. When later transplanted to verticillium-infested fields, these plants sustained much less damage than untreated plants. (0582W443-5)

Balanced Rations Improve Milk for Cheese

Nearly one-third of all milk produced in this country is now used for cheese production, but the current milk pricing system is geared towards fluid milk with lower milk fat. Animal scientist Robert C. Lamb, Logan, Utah, points out that this inequity poses problems for cheese producers who pay too little for milk with high fat and protein, and too much for milk with low fat and protein.

To correct this inequity, a cheese-yield milk pricing system was developed by Lamb's colleagues at Utah State University, Logan. Under this system, pricing is based on the amount of cheese that can be made from 100 pounds of milk as determined by its fat and protein content.

"The best cheese-yield comes from milk that contains 80 percent as much protein as fat," says Lamb.

Feed is the major means available to producers for quickly changing the composition of their cows' milk. However, there are limitations. Says Lamb, "Environmental factors that affect fat content also affect protein but often in opposite directions."

Lamb especially cautions against trying to increase milk protein by adding more protein to a cow's feed. "Protein consumed beyond the cow's requirements will not increase the protein content of her milk because she synthesizes the protein that appears in her milk."

Balanced rations are the key to effective change. "A dairy producer would be best advised to get professional help with balancing rations by contacting either the Extension Service or other nutritional consulting groups," Lamb says.

Lamb has written a publication entitled "Managing Dairy Cows to Improve Protein Content of Milk." Copies of the publication can be obtained from the Utah Agricultural Experiment Station, Utah State University, Logan, UT 84322. Request Research Report 61, and specify for Holstein or Jersey cows.

Robert C. Lamb is located at Room 205, Agricultural Science Bldg., UMC 48, Utah State University, Logan, Utah 84322.—(By Lynn Yarris, Oakland, Calif.)■

Wanted: Aggressive Sterile Caribflies

A study of the mating habits of wild Caribbean fruit flies in their natural environment may also be of help to State and Federal control agencies battling that pest's more notorious cousin, the Mediterranean fruit fly, better known as the medfly. Although the 1981 medfly invasion of California citrus groves is now under control, careful monitoring continues.

Both the Caribbean fruit fly and the medfly usually mate in aggregations or groups on the foliage of a host plant, an important similarity.

Results from the new mating study on the Caribbean fruit fly, commonly called the caribfly, could provide guidelines for determining the aggressiveness of laboratory-reared sterile males which must compete for females against wild males. Also, the study shows that most male flies mate more successfully in aggregations than when isolated. This finding may enable researchers to devise better ways of detecting and trapping the fruit flies.

According to entomologist Theodore Burk, "Biological control efforts depend on the successful mating of sterile males we release into infested areas. Our sterile males may look good to us, but what counts is how they perform in a mating situation in undisturbed wild populations. We need to understand two important aspects of mating—competition between males and the female's choice of her mate."

Burk studied the wild caribfly's mating behavior in a 40-meter-long Surinam cherry hedge and a 60-meter row of guava trees in south Florida. The flies prefer these particular hosts. Grapefruit is their only important citrus host.

From late May to early October, Burk made 214 hourly census counts to record the sex, location, and behavior of all the caribflies he saw. These are some of his observations.

- Both males and females were most active on fruit in the early morning when light intensity and temperatures were low. On fruit, female flies were usually either feeding or probing and dragging their ovipositors on the surface of the fruit, depositing a pheromone (sex attractant), and occasionally rupturing the fruit to deposit eggs. Males were either feeding or following and courting females, not too successfully. By midmorning the flies moved to positions under shaded trees.
- In the late afternoon, males fought for single-leaf territories, "puffed" to produce sex pheromone, and "called" with acoustic signals. Puffing is part of the male's vigorous sexual display; he expands the pleural region of the abdomen, and extrudes a clear pheromone droplet onto the leaf surface. Puffing males also call, with short bursts of rapid wing vibrations to produce acoustic signals. Almost all matings took place after the females were attracted by these displays. Males, therefore, had two ways to mate: searching for females on fruit, and displaying under leaves. This is the first report of dual mating methods by male caribflies. However, displaying on leaves was by far their more successful method.
- Territorial fights were an important part of successful mating. To mate, a male must be in possession of a leaf territory where he can puff and call, and must be near other displaying males. He must successfully fight off rivals who compete for "calling stations" within their aggregation. These aggregations (called leks) are a prerequisite for attracting females.
- Females observed leks and responded to whichever territory-holding, displaying male they chose, mating more often with the most vigorous, dominant males.

Burk says, "A female choosing a mate is acting essentially the same way as an entomologist concerned with the quality of the sterile flies he is rearing and releasing. Sterile males must fight off wild males and attract more females. We found that male aggressive ability and factors such as size are likely to be very important in reproductive success."

Burk suggests that the use of quality control tests at insectaries to determine male aggressive ability may be the logical next step in the battle against fruit flies.

Theodore Burk, recently with the ARS Insect Attractants, Behavior, and Basic Biology Research Laboratory, Gainesville, Fla., is now located at Creighton University, Dept. of Biology, Omaha, Nebr. 68178.—(By Peggy Goodin, New Orleans, La.)■

Cotton "Yields" to Ozone

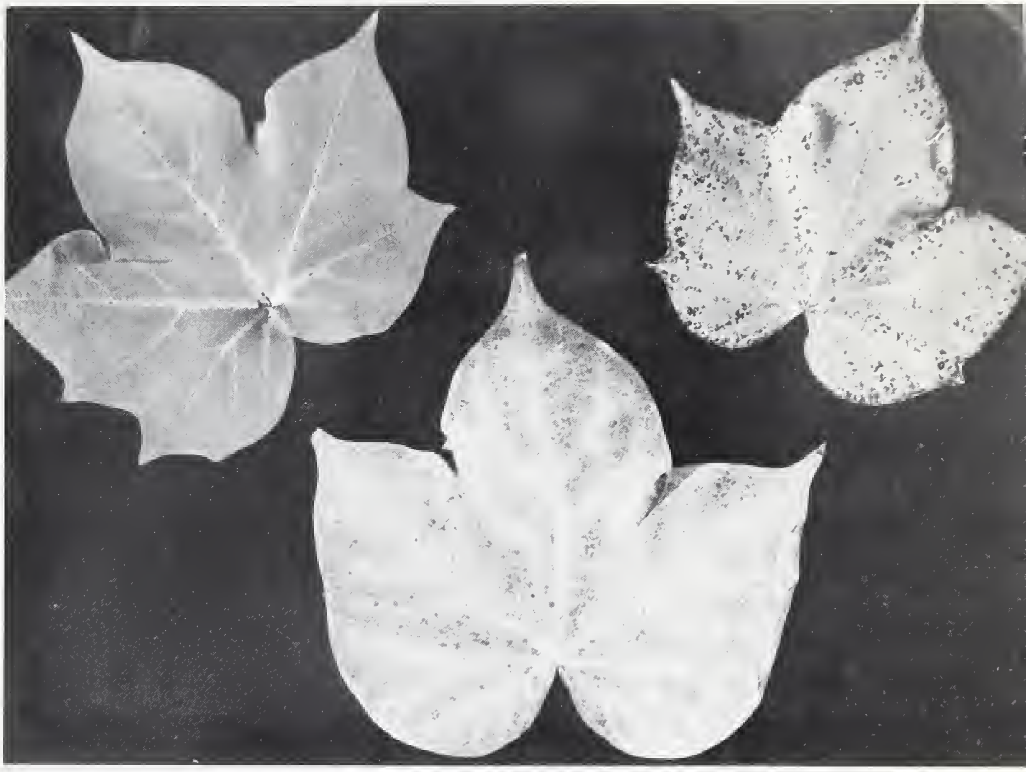
Air pollution may be depressing the production of cotton, the Nation's No. 4 crop, whose yields have stagnated at mid-1960's levels.

Howard E. Heggestad, ARS plant pathologist, Beltsville, Md., says that cotton yields doubled between 1946 and 1966 due to improved varieties and better production methods. Subsequent yields have plateaued, possibly even decreased, despite better varieties. Based on his studies and those of other scientists, Heggestad concludes that "ozone air pollution is clearly having some impact on cotton yields," and suggests the need for productive, pollution-resistant varieties.

Ozone gas, primarily a product of the action of sunlight on auto exhausts, is a ubiquitous pollutant in the United States, accounting for about 90 percent of all crop loss due to air pollution, says Heggestad, who is a member of the National Crop Loss Assessment Network sponsored by the Environmental Protection Agency. Sulfur dioxide ranks as the second most common pollutant, but its damage to crops is generally confined to areas downwind of large stationary sources such as electric power plants and metal smelters. Both pollutants cause damage to the plant's leaves which, in turn, causes loss in yield. Cotton leaves are most sensitive just before they are fully expanded.

Other localized chemicals such as fluorides, ethylene, nitrogen oxides, and drifting pesticides can add insult to injury. "It is the prolonged exposure to low levels of pollutants and mixtures of pollutant that concerns us most. Current pollution abatement technology seems adequate to protect leaves from acute damage," Heggestad says.

Most of the air pollution studies involving cotton were conducted in California, where ozone levels are highest among cotton-producing states. To gauge the effects of pollutants, researchers grow cotton plants in "normal" (ambient) air and in charcoal-filtered air, then compare their yields. The most popular California variety, Acala SJ-2, showed about 15 percent loss due to photochemical smog. Another California variety, Acala SJ-5, showed more resistance to ozone than SJ-2, but yielded less.



At left is a green, healthy leaf from a cotton plant grown in a greenhouse where most of the ozone was removed from the air. By contrast, the middle leaf displays considerable yellowing, and the older leaf (right) has turned red and brown and developed lesions after being grown in nonfiltered ambient air with the usual levels of ozone. (BN-49549)

Heggestad points out, however, that ozone tolerance and high yield can be bred into the same variety, citing field corn and tobacco as examples.

In Heggestad's own series of greenhouse studies at Beltsville, Md., he compared eight of the most commonly grown varieties. Levels of ozone existing in the Beltsville area produced significant yield losses and changed lint and seed quality in four of the eight varieties. The four varieties that fared best were: Stoneville 213 (bred for the Mississippi Delta), Acala SJ-1 (San Joaquin Valley), PD 3246 (South Carolina), and Acala 1517D (Mexico and El Paso, Texas).

Heggestad says his tests and others around the country show that the Acala varieties developed at Shafter, California—a high ozone area—have best withstood such pollution.

Heggestad recommends running field tests in the Mississippi Delta and parts of Texas to determine whether levels of ozone existing there reduce yields of these and other varieties. U.S. growers currently rely on about 12 major varieties of cotton.

At present, damaging levels of sulfur dioxide are localized. Should such levels increase significantly with the current increased use of coal, the combination of ozone and sulfur dioxide could cause even more crop loss, Heggestad cautions. His studies have already demonstrated this additive effect on yields of green beans, soybeans, and tomatoes.

Howard E. Heggestad is located in Rm. 229, Bldg. 001, Beltsville Agricultural Research Center-West, Beltsville, Md. 20705.—(By Judy McBride, Beltsville, Md.)■

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Agrisearch Notes

Subsurface Drainage Curbs Erosion

Subsurface drainage is usually installed to boost crop production, but computer simulation studies show that this practice may also help curb soil erosion.

By draining a soil the farmer increases its water holding capacity. More precipitation or snow melt can then infiltrate into the soil, thereby reducing the amount of surface runoff that could erode the land.

To analyze the effects of supplemental drainage on erosion, two computer models called DRAINMOD and CREAMS were combined by ARS hydraulic engineer George R. Foster, Lafayette, Ind., and engineers R. Wayne Skaggs and Abdolhossien Nassehzadeh-Tabrizi of North Carolina State University, Raleigh.

DRAINMOD, developed by North Carolina State University, predicts on an hour-by-hour basis, the position of the water table, soil water content, drainage, evapotranspiration, and surface runoff.

CREAMS, developed by ARS, predicts on a storm-by-storm basis, runoff, erosion/sediment transport and movement of plant nutrients and pesticides from field-sized areas.

The three researchers devised a computer simulation to determine whether supplemental subsurface drainage should be considered a "best management practice" for Goldsboro sandy loam soil with a 2-percent slope in eastern North Carolina. Their model incorporated climatological records collected over a 10-year period from Wilmington, N.C.

The simulation showed that a field of conventionally tilled corn with good surface drainage but poor subsurface drainage annually lost 4 tons per acre. In contrast, soil loss on a field with poor surface drainage but good subsurface drainage was only 0.4 tons per acre.

About 50 million acres in the eastern United States need supplemental drainage for efficient agricultural production, Foster says. Since much of the land is near environmentally sensitive areas where even small amounts of erosion are objectionable, any soil savings achieved with drainage systems would be an added bonus.

George R. Foster is located at the National Soil Erosion Laboratory, Purdue University, Building Soils, W. Lafayette, Ind. 47907.—(By Ben Hardin, Peoria, Ill.)■

The Benefits of Short-Statured Cotton

Early maturity in some of ARS's developmental varieties of long-staple cotton seems to result from the varieties' short stature.

Kenneth E. Fry, ARS plant physiologist at Phoenix, Ariz., says the short stature of the new varieties creates less internal shade. This results in fewer squares and bolls being shed. Internal shade in many current varieties of cotton is believed to be responsible for excessive fruit shed.

Early flowering and maturing of cotton bolls is highly desirable because it cuts growers' costs for labor, chemicals, and other production practices. Furthermore, it conserves water resources, an issue of increasing concern in the Southwest.

Fry, along with ARS agronomists Carl V. Feaster and E. Fountain Young, also at Phoenix, examined the short-statured plants after harvest for clues to why they matured earlier than the current Pima S-5 variety.

They found that the plants fruited more heavily on the lower fruiting branches than on upper ones. This meant that their major fruit load set earlier than that of Pima S-5. Also, more of the fruits on the nodes nearest the main stem were retained to maturity, and there were more fruits set at the main stem nodes than on Pima S-5.

Although flowering rates were similar for both old and new varieties, the latter became fully loaded sooner because of their superior fruit retention.

Another characteristic of the new varieties which may be related to earliness is the setting of two fruits at a fruiting branch node where one is common.

"Using post-harvest measurements to obtain such relationships and to quantify the plant characteristics related to earliness of different varieties should be useful to the cotton breeder," Fry says.

Kenneth E. Fry is located at the Western Cotton Research Laboratory, 4207 E. Broadway Rd., Phoenix, Ariz. 85040.—(By Paul Dean, Oakland, Calif.)■